

# TJR App a Mobile App for Shared Informed Decision Making in Total Joint Replacement Surgery

## **Final Report**

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## **STRUCTURED ABSTRACT**

### **Purpose**

The objective was to develop a mobile app that helps osteoarthritis (OA) patients keep track of their pain/activity and provides access to the patient-centered outcome prediction models designed for advanced knee arthritis patients and their clinicians to support shared treatment decisions.

### **Scope**

OA is the number one cause of disability in the US and affects more than 60% of adults over 65 years. Mobile health tools can be an optimal method for OA care but are scarcely available for patients with OA. The TJR App was designed to address this gap in OA self-care.

### **Methods**

Using focus groups and interviews with 10 patients and 3 clinicians as part of our iterative user-centered design approach, we developed an Android-based smartphone app. We conducted usability sessions with 6 patients to assess usability and a pilot test with 12 patients using TJR App for 2-weeks prior to their visit at the clinic while receiving standard care, and we collected survey data from 16 patients, who only received standard care at the joint clinic, after their clinic visits.

### **Results**

TJR App was developed using an iterative user-centered design process with involvement of more than 30 potential users (patients and providers). The usability rating of the app was in the acceptable range. Participants thought TJR App would allow more data-driven conversations with the doctor, collect data-based evidence regarding their condition, lead to more informed questions and active participation in the decision-making process during visits.

### **Key Words**

osteoarthritis, mobile Health, mHealth, mobile app, self-care, self management, arthritis

## **PURPOSE**

The objective of this study was to develop an Android-based smartphone app, TJR App, that helps patients suffering from osteoarthritis (OA) keep track of their pain/activity and provides them access to the patient-centered outcome prediction models designed for advanced knee arthritis patients and their clinicians to trend pain and disability to support shared treatment decisions. We designed our study in three specific aims to achieve our objective.

Specific Aim 1: TJR App Development – Our goal was to develop TJR App using user centered design principles that rely on engagement of potential users in the design and development of the application. We planned to achieve these using joint application design sessions at different stages of development where patients with OA and clinicians who treat patients with OA participated and provided design ideas and suggestions while reviewing our design options.

Specific Aim 2: TJR App Usability Testing – Our goal was to assess the usability of TJR-App with arthritis patients and clinicians in the laboratory and clinic settings. Laboratory usability tests supported iterative improvements informed by participants who are patients with OA. Field usability tests were used to understand issues related to implementation of our app in clinical settings.

Specific Aim 3: TJR App Pilot Testing – Our goal was to conduct a small feasibility study with 30 patients with knee arthritis. We assigned them into two groups: 1) TJR App users capturing two-weeks of pain and function profiles, 2) office-based (single point) patient reported symptom surveys. Following the office visit, we interviewed patients about their satisfaction, patient level of engagement in decision-making, and clinician knowledge of patient symptom severity, function, and goals. We hypothesized that the TJR App users will be more engaged and informed as compared to control group.

## **SCOPE**

Mobile technology allows efficient, 24/7 collection, processing, and dissemination of information, including patient reported outcome measures. Based on the 2014 Pew report, six in ten seniors - 59% -reported using the Internet; 74% of seniors in the 65-69 age group and 68% of the 70-74 group go online.<sup>1</sup> In 2014, 29% of seniors in the 65-69 age group and 21% of the 70-74 group owned a smartphone, compared to 39% of those aged 55-64 years. By 2016, the Pew survey found 42% of US adults over 65 years and 74% of those aged 50-64 owned a smartphone.<sup>2</sup> Older adults' use of the Internet and smartphone has been increasing steadily each year since the Pew Research Center began systematically tracking Americans' internet and mobile technology usage. This trend suggests that an mHealth App can be an optimal method for OA care. However, to date, mHealth tools have not been integrated into patient self-care or medical decision-making for patients with advanced knee osteoarthritis (OA).<sup>3</sup>

Osteoarthritis (OA) is the number one cause of disability in the US and affects more than 60% of adults over 65 years.<sup>4</sup> There is no cure for OA so patients use chronic pain medications and physical therapy to limit the associated disability. When medication and rehabilitation are no longer effective, total knee replacement (TKR) is the most common treatment. TKR effectively eliminates arthritis pain and improves function, on average, making TKR surgery the

highest volume inpatient procedure. Total knee and hip replacement surgeries account for more than one million hospitalizations annually.<sup>5</sup> Medicare is the primary insurer for over 50% of patients, yet almost 50% of patients are under 65 years of age. In 2011, there were 376 Total Joint Replacement (TJR) discharges per 100,000 adults, representing a 65% increase in utilization since 2001. As the population ages, the overall utilization of knee replacement is projected to increase by 600% by 2030.<sup>6</sup> Thus, optimal decisions regarding medical treatment of knee OA and the timing and use of TKR is a public health priority.

OA is a chronic degenerative condition. Thus, treatment goals are to slow progression and minimize symptoms. Patients need up-to-date evidence to inform them of the relative benefits and risks of alternate OA treatments. For example, the 2015 American Academy of Orthopedic Surgeons clinical guideline statement reviews effective and ineffective knee OA treatment options.<sup>7</sup>

*Medications for OA.* Patients with moderate-to-advanced OA use anti-inflammatory and pain medications to manage knee OA symptoms. Chronic pain medications are challenging in patients with multiple co-morbidities. For example, non-steroidal anti-inflammatory drugs (NSAIDs) are widely used to treat OA, but are associated with 3,000-16,000 deaths/year from gastrointestinal complications.<sup>8</sup> AHRQ guidelines emphasize personalizing medication treatment to patient preferences and risk profiles. ([www.effectivehealthcare.ahrq.gov](http://www.effectivehealthcare.ahrq.gov)).

*Exercise and physical activity in OA.* Physical activity guidelines for OA patients are designed to reduce pain and improve function. Regular, low-to-moderate exercise delays disability, improves physical function and mental health, aerobic capacity and muscle strengths; it also reduces pain and decreases the risk of weight gain.<sup>9, 10</sup> In knee OA, the combination of diet and aerobic exercise resulted in significant improvements in physical function and knee pain.<sup>11</sup> Finally, a recent randomized trial compared comprehensive physical therapy and total knee replacement directly and observed significant pain relief with both treatments, with TKR offering greater pain relief than physical therapy.<sup>12</sup>

*Total knee replacement.* If non-operative treatments are no longer effective in managing OA pain, TKR surgery is proven effective.<sup>13</sup> While TKR offers consistent pain relief, functional gains after TKR vary widely based on pre-operative patient factors. For example, at 6 months after TKR, while more than two-thirds of patients report improved function scores, one-third of patients do not.<sup>14</sup> Growing evidence describes multiple patient risk factors for sub-optimal functional gain after TKR.<sup>14, 15</sup> Thus, patients must carefully consider treatment options, and if TKR is preferred, should be aware that pre-existing clinical risk factors may influence post-operative functional gains.

*OA disease burden metric.* Despite extensive research, no biomarker of OA progression has been adopted in clinical care and OA signs identified on physical exam or with knee imaging do not consistently correlate with pain or symptom severity. Today, many arthroplasty surgeons routinely assess pain and function in knee OA patients using standardized, validated patient-reported outcome measures (PROs). For example, the FORCE-TJR national research cohort collected the most commonly used knee OA PROs, the Knee OA and Injury Outcome Scores (KOOS),<sup>16-18</sup> on more than 16,000 knee arthroplasty patients.<sup>19</sup> The KOOS includes all items of the WOMAC, a legacy knee OA research PRO, so the KOOS is emerging as a standard PRO metric that patients can readily monitor. With funding from AHRQ (P50HS018910), the FORCETJR national cohort includes patients of over 200 surgeons practicing in 28 states and

diverse settings (e.g., academic vs. community, urban vs. rural) and patients from diverse socioeconomic, racial-ethnic and geographic backgrounds. In 2016, the KOOS was included in the new CMS joint replacement bundled payment model to quantify joint-specific symptoms before and after TKR.<sup>20</sup> While surgeons are adopting PROs, primary care practices do not routinely use PROs to monitor and manage knee OA care.

The TJR App was designed to address this important gap in OA self-care and shared decision making by allowing patients to track their pain and activity and to assess PROs and key risk factors for review with the clinician.

## **METHODS**

### **Specific Aim 1: TJR App Development**

TJR App was developed through a user-centric iterative design process. The initial version of the app was informed by existing mHealth applications that target pain and arthritis as well as the input from patients collected in our former studies. TJR app was further refined through two sessions of focus groups with patients (1<sup>st</sup> focus group with 5 patients on December 2, 2015 and 2<sup>nd</sup> focus group with 5 patients on January 28, 2016) to gather additional requirements and produce the first viable version. This version was assessed during three key informant interviews with providers (1<sup>st</sup> interview with a physical therapist on May 19, 2016; 2<sup>nd</sup> interview with a physical therapist on June 2, 2016; 3<sup>rd</sup> interview with a surgeon on July 8, 2016).

Focus Groups with Patients Inclusion Criteria: All adults 55 years of age and older with the primary diagnosis of knee osteoarthritis (OA), seeking care at the UMMS Arthritis and Joint Center (AJC) and able to understand and evaluate the app, speaks and reads English, and is able to provide informed consent were invited. Access to or familiarity with an Android smartphone, as we ask participants their opinions regarding a proposed new app for making treatment decisions, was required.

Focus Groups with Patients Exclusion Criteria: Adults unable to consent due to cognitive barrier, pregnant women or prisoners

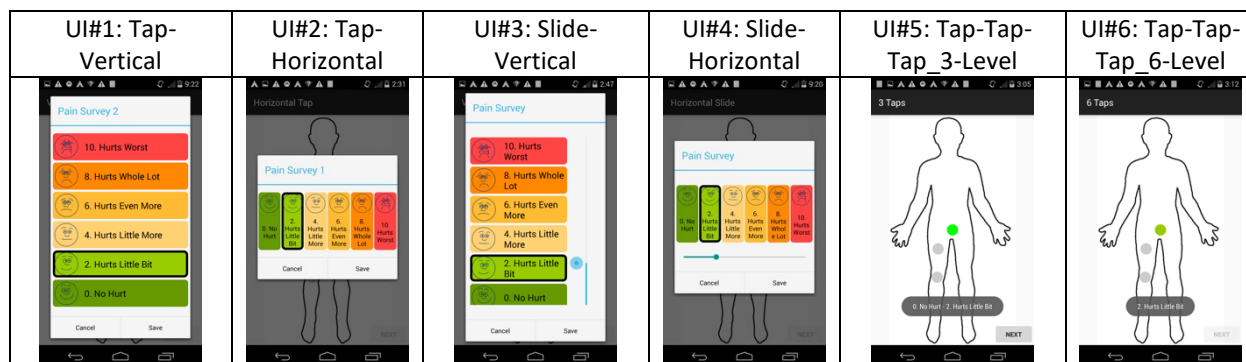
Interviews with Providers Inclusion Criteria: Surgeons and non-surgeons (i.e., Physician Assistants, Rheumatologists) treating patients in the AJC and FORCE TJR network were invited to interviews.

Requirements gathering session were conducted in the form of face-to-face focus group with participants that meet the inclusion criteria with the goal of understanding patient preferences for graphic displays of data, assessment questions, and progress results. In the first focus group, we introduced the prototypes (in paper or power point) we developed and the existing apps related to OA to the participants, encouraging them to provide ideas about the functional requirements and design preferences for the TJR App. In the following focus groups, we introduced TJR App prototypes developed based on the input from the previous focus groups as we continued to seek feedback and ideas from participants.

As part of the focus groups, we also conducted an experiment that aimed to find the easiest and the least effort-demanding user interface (UI) type for frequent data input tasks, such as pain data input, where users are required to input data multiple times a day using a smartphone. We developed six different types of UIs that had different touch types (e.g., tap vs.

slide) and/or different touch directions (e.g., vertical vs. horizontal). Each participant in the focus group was given a test phone with the app and asked to input certain levels of data for three different joints (back, left hip, and left knee joints) as quickly and as accurately as possible (Table 1). We recorded task completion times and error rates. We also conducted a follow-up survey asking about their perceptions of easiness and usability of the six UIs under investigation. The literature is not conclusive about the appropriate interface option for frequent data entry requests on smartphone apps. Our goal was to close this gap by providing empirical evidence. Overall, the entire process of the focus group was guided by the protocol we developed.

*Table 1 Six Different User Interfaces for Pain Data Input*



Through the activities, we gained a better understanding of the patients' expectations about a mobile app for OA management. In particular, the first patient focus group provided us with a better sense of how TJR-Decision should look like in terms of functional requirements and design. Based on the feedback from the first focus group, we started developing the next version of the app prototype. Also, we revised the focus group protocol to allow users to experience the TJR app main navigation, pain data input and progress report as functional prototypes of TJR app became available.

Clinician interviews were conducted online via a teleconferencing system (2 participants) or face-to-face (1 participant) where the clinicians had access to our first version of the TJR app and use videos. The purpose of these interviews was to understand clinicians' preferred presentation of patient data and evaluation results. Feedback from these interviews helped us design and refine the assessment report feature of the app that is designed to facilitate shared decision making. Interviews started by the interviewer introducing the app and its features followed by participants providing feedback about each feature.

All focus groups and interviews were recorded for data analysis. The team of developers and investigators reviewed the themes that are extracted from the interviews and decided on the changes needed to be made for the next iteration of the app. This iterative process resulted in the first fully functioning prototype.

## Specific Aim 2: TJR App Usability Testing

We used the same inclusion/exclusion criteria presented in Aim 1 for the two lab usability sessions conducted using the fully functioning iterations of the TJR App. First lab usability test session was conducted in March 18, 2016. Second lab usability session was

conducted in May 12, 2016. Both sessions had 3 participants who were older adults (55+) suffering from knee arthritis. The goal of these sessions was to allow users to go through a set of use scenarios developed by the investigators without the help of others and discuss their experience and ways we can improve the app and their user experience. Based on the feedback received from the first lab usability session, we made changes to the app before we moved onto the next lab usability session. At the end of the second usability session, we decided that we achieved saturation in the type of feedback we were getting from the users and decided to move to the next phase, field usability, after final set of iterations. In addition to the qualitative comments that were collected and analyzed during the lab usability session (including recordings of the participants comments and observations of the investigators while the participants were navigating through the use scenarios), we used System Usability Scale (SUS) questionnaire to quantitatively measure the usability of our system.<sup>21</sup>

For the field usability study, we modified the inclusion criteria (18 years of age and older with the primary diagnosis of knee OA, seeking care at the UMMS AJC and able to understand and evaluate the app, speaks and reads English, is able to provide informed consent, and has access to an Android smartphone) to achieve the original recruitment numbers. We recruited 4 participants (older adults +55 with knee OA) for the field usability study. One of the participants dropped out of the study due to incompatibility of the Android version on their phone. Three participants completed the field usability study in which we asked them to use TJR App before their scheduled visit with their provider and to provide us feedback after their visit during a phone interview. These interviews were recorded and analyzed to identify ways we can improve the app. We also asked the participants to answer SUS questions to have a quantitative measure of usability.

### **Specific Aim 3: TJR App Pilot Testing**

During this phase, we developed a web-based provisioning system which allows us to manage users of TJR App and their data. Our study was designed to randomize 30 patients into two conditions: (1) patients using TJR App before their visit to monitor pain and function and receiving standard care during their visit and (2) patients receiving office-based (single-point) patient reported symptoms survey (standard care at UMass). All adults 18 years of age and older with the primary diagnosis of knee OA, seeking care at the UMMS AJC and able to understand and evaluate the app, speaks and reads English, and is able to provide informed consent were invited to the study. For those assigned to condition 1, they also had to have access to an Android smartphone.

Condition 1: We recruited 12 patients who are scheduled to visit the joint clinic at UMass 1 month before their visit. Among 12 participants, 3 of them dropped out of the study and 9 completed the study. We asked participants to use the TJR App during 2 weeks and we scheduled a phone interview with them after their visit. We provided them with a unique username and password, as well as instructions (video tutorials) that demonstrate how to utilize each feature of the app. In this phase we had two major interests. We were interested in understanding the challenges of recruitment for a future intervention study, best approaches to recruit patients, and feasibility of running a potentially longer study in the future. We were also interested in learning whether users find TJR App useful during their visits or for their OA self-care management and how they used it. We transcribed the interviews and downloaded the

user data in our provisioning system. Both data sets were analyzed to understand utilization patterns and needs.

Condition 2: We recruited 16 patients who had a scheduled visit at the joint clinic at UMass while they were waiting for their visits. They were asked to complete a paper-based survey which asked them if they would consider using App for tracking their pain and function, if they would like to fill out the pre-visit assessments at home using an app, and how an app that helps them keep track of their pain and activity could help during their visit at the clinic.

## Limitations

Our study was designed as an exploratory study. Our findings are based on a small sample recruited from a single joint clinic in Massachusetts (see Table 2 for participant characteristics) because the primary goal of our study was to develop a fully functioning and usable application – based on the iterative user-centered design principles – that helps patients with arthritis keep track of their pain and function. Future studies should focus on understanding the effects of using TJR App (a tool that facilitates arthritis self-care and provides information about disease progress) on shared decision making, changes in function of the joints, changes in pain levels due to increased awareness of pain triggers while using the app, and changes in recovery progress after surgery due to app use.

*Table 2 - Participant Characteristics*

	n	%
<b>Gender</b>		
Female	14	50%
Male	14	50%
<b>Age</b>		
<65	11	39%
>=65	17	61%
<b>Race</b>		
White	28	100.0%
<b>Ethnicity</b>		
Not Hispanic or Latino	28	100.0%

## RESULTS

### Principal Findings and Outcomes

#### Specific Aim 1: TJR App Development

We developed the TJR App after conducting reviews of existing pain apps on app stores, literature review on mobile health app development and design guidelines, and multiple patient focus groups that help us determine the needs of users from a mobile app that supports their management of OA related pain.

During our survey of online app stores (Google Play and Apple App Store), we identified four relevant apps on the market (TRACK + REACT by Arthritis Foundation; MyRA by Crescendo Bioscience, Inc; RheumaTrackRA by Axovis GmbH; and iOrtho by Articulations LLC). We

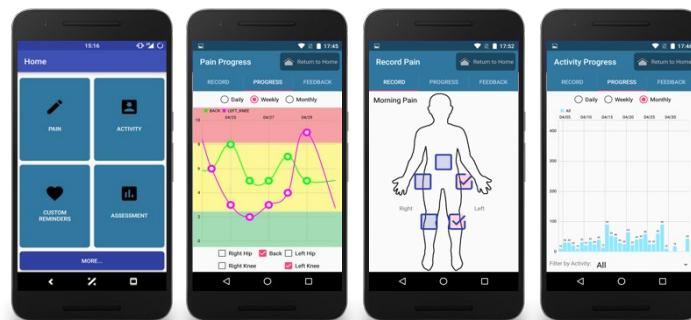
determined common and unique functionalities, design features, and data presentation forms in the existing apps for osteoarthritis (OA) or other types of arthritis. We developed an initial list of requirements for the app and a design of the system architecture. We used this new knowledge to develop mock interface prototypes of TJR-App (using paper and slide presentation software).

During 3 different focus groups with patients who had knee replacement surgery, we shared our iterative prototypes with the participants to collect feedback and conducted an experiment to test the effects of different user interface (UI) types on users' performance in pain data entry and perceptions of UI design (Table 1). We learned that (1) while some users are interested in tracking their pain, others are skeptical about it, (2) users expect some sort of feedback from the app that is actionable such as "to relieve your pain, elevate your leg" or "apply cold for your knee pain" and they do not want to see any negative indicators in the feedback (e.g., downward arrow or thumb-down icons), (3) some users are interested in seeing their data visualized in detailed charts, while others prefer to see short text based feedback such as "your pain is worst this week compared to last", (4) users are interested in having medication management and stiffness recording be part of the app, (5) users are interested in the app providing recommendations for exercise that would be helpful for managing OA pain but they want to have multiple options to choose from and they would like the ability to add their own activities if it is not provided in the app, (6) users prefer single tap-based over slide-based UIs and tap-based data entry UIs require less time for data input compared to other UIs, but users want the tapable area to be very large for easy interaction with the app, and (7) users do not find visual indicators (color and faces) on the pain scale necessarily useful, and (8) users are interested in useful tips and links to educational content regarding osteoarthritis from credible sources.

During clinician interviews, we learned that (1) clinicians find patient's pain history data useful but depending on the clinician type the preference for data granularity (daily, weekly, monthly, etc.) changes (e.g., surgeons may prefer monthly or quarterly summary views with long term trends where as physical therapists may find daily data useful as they help their patients), (2) some clinicians are concerned about the unintended consequences of daily pain entry (i.e., could make patients focus on their pain more than necessary), (3) clinicians want to see the trend lines with the pain and activity data, (4) clinicians suggest providing educational content and feedback regarding OA-specific PT activities to emphasize the importance of the self-management, (5) clinicians suggest indicating intensity level with specific activities (e.g., stationary biking or treadmill walking) because these indoor activities can result in patients hurting their joints more if they are not done carefully, (6) clinicians suggest recommending users to fill out the assessment questionnaire when they have a significant change in their symptoms, but no sooner than a month, (7) clinicians believe providing patients with the ability to compare their progress against others could be helpful, and (8) clinicians believe collecting the range of motion (ROM) data, especially for patients in the post-surgery phase, can be useful.

Based on the feedback received during the iterative process of gathering requirements through patient focus groups and clinician interviews, we made many minor (e.g., adjusting the location of OA joints (e.g., knees, hips, and back) on the body figure, adding a goal line to the activity graph) and some major changes to our original design (e.g. adding a graphs tab under

the assessments section to present clinician-oriented data visualization in the app in addition to the patient-oriented data visualization under the pain and activity progress sections) to develop the first version of our TJR App with four major functionalities—pain and activity data recording and monitoring, reminders, and assessment. Figure 1 shows the main screen of TJR App (first picture from the left), pain progress graph (second picture), pain data entry page (third picture), and activity progress graph (fourth picture). We also developed algorithms to provide weekly feedback for pain and activity progress to users, including a pool of feedback messages for pain (16 messages) and activity (17 messages), from which the most relevant/useful message will be selected for the data entered by the patient. We also mapped FAQs (included in the app based on the content created under TJR-Force project at UMass) to certain feedback messages for pain and activity to enable the app to provide data-driven, context-specific feedback and educational content to users.



Using more than 10,000 TKR patients from the FORCE-TJR data with broader measures and higher quality than the prior data, we refined the prediction models to stratify knee replacement patients into those likely to achieve greater or lesser functional gains. The refined model incorporates several new risk factors identified in FORCE-TJR data, such as musculoskeletal comorbid indices, patient socioeconomic status, and health behaviors (e.g., smoking). Such data were not available, or limited, in previous studies. We use the updated risk prediction model to guide the TJR-App and inform outcome evaluation. Importantly, these models initially used an aggregate function score (SF36 or KOOS: Knee OA Outcome Score) as the dependent variable (outcome), a score that is not immediately relevant to patients. Following patient interviews, these prediction models were transformed to models to predict three patient-centric items: 1) severity of pain at rest, 2) pain when walking, and 3) walking distance at a year post-surgery.

### Specific Aim 2: TJR App Usability Testing

**Lab Usability Testing:** We developed use scenarios that guide participants during the lab usability sessions to explore the functionality of TJR App: (a) pain data input and progress monitoring, (b) activity data input and progress monitoring, (c) assessment completion and report viewing, and (d) managing reminders. Overall, the average system usability scale (SUS) score was 75 out of 100, which indicated that the usability of the app was above average. We reflected on users' feedback and refined the app before moving into field usability.

Field Usability Testing: We recruited 3 field usability users who have scheduled appointments with a provider in UMass Joint Clinic in the next two months. Participants were asked to use the app for a week and discuss the app data with their provider during their visit. Feedback from 3 post-visit interviews with field usability test participants (1st interview on March 1, 2017; 2nd interview on March 17, 2017, 3<sup>rd</sup> interview on May 17, 2017) indicate that users find TJR App easy to use. All three participants used Pain and Activity features of the app most frequently. Two participants used custom reminders and thought this was a useful feature. One participant did not use custom reminders. All participants completed the assessment survey which includes PROs. Even though two of the participants did not have a chance to discuss the assessment results in the app with their doctors during the visit, they thought having this discussion during the visit would be a good idea. One participant who discussed his results in the app with his provider thought that the app helped communicate with the doctor better during the visit. All participants indicated that they would use the app if their doctors recommend them to do so and they all considered that the app is useful in OA self-management and would recommend it to other people. The average system usability scale (SUS) score was 89 out of 100, which indicates that the usability of the app is “excellent.”

### Specific Aim 3: TJR App Pilot Testing

We analyzed the data from pilot study participants further. Overall, we received positive feedback from all participants who were assigned to the TJR App use condition. These participants received standard care and, in addition, experienced downloading the app and using it for two weeks. The key findings from the analysis of their interviews are below:

- All participants used the daily pain reporting feature consistently. One participant thought that on days which she felt no pain, she did not need to record her pain. This was an important finding indicating that some users may actively keep track of their symptoms only if the pain is impacting the user’s daily activities negatively.
- Some participants used the activity reporting regularly, others used it sporadically. One participant thought that the activity referred only to activities associated with physical therapy and recorded only those activities. This finding is important as we design guidelines for users. Activities that users are expected to log should be clearly defined with examples.
- Most of the participants mentioned that the app could have been very useful to them in the earlier stages of OA. They mentioned that now that they have been experiencing pain for a long time (we recruited patients from the surgical unit where they are seen for TJR decisions, indicating that they already have been suffering from severe pain for a while), they became quite knowledgeable about their own patterns and their condition. The FAQs and other educational material in the app including their pain patterns were common knowledge to them at this point in their disease progression. This finding identifies an opportunity for early OA diagnosis and promotion of self-care.

During our interviews with participants who completed our pilot study (n=9), most users indicated that they found TJR app easy to use and useful. The System Usability Scale (SUS) scores (Figure 2) TJR app received from the participants (avg=84.2, std.dev=9.8) support this finding as well. All of the scores were in acceptable usability range. Most of the scores were in the range of excellent to best imaginable adjective ratings.<sup>22</sup>

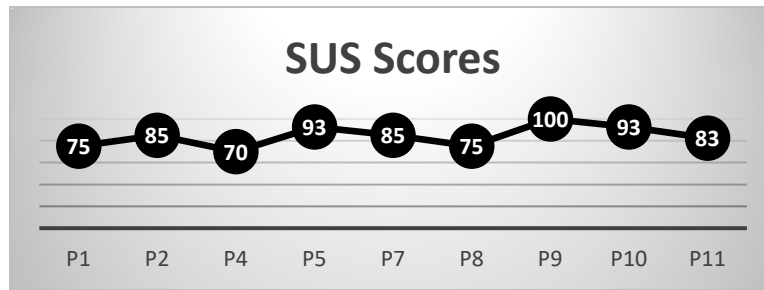


Figure 2 System Usability Scale Scores for all participants

We prepared a survey for the control group based on the feedback we received from TJR App users. We included 4 key benefits identified during our data analysis as ways use of TJR App can help patients during a visit (Table 2). The response from the 16 participants in the control group showed that none of them kept track of their pain in a systematic way (on paper, in an app, or any other system). Five out of 16 participants said that they would be interested in using a mobile app to track their pain and activity. Moreover, 4 of these 5 would also be interested in completing assessment surveys at home using an app. Two out of the 16 participants indicated that they may be interested in using an app for tracking pain and activity as well as completing assessments at home. On the other hand, 9 participants indicated that they would not be interested in using an app. When asked how would keeping track of pain and activity with an app affect their visit experience, only 6 of them responded (Table 2) but we received at least one positive response to all the benefits identified during our interview analysis.

Table 3 Control Group Participants Responses to "How do you think keeping track of your joint pain and physical activity in an app would affect your visit experience or help you during your visit with the doctor?"

Responses	N
Allow me to have more data-driven conversations with the doctor	3
Help me provide data-based evidence regarding my condition	2
Help me ask more informed questions	4
Help me participate actively in the decision making process during my visit	4

## Discussion

TJR App was developed using an iterative user-centered design process to allow potential users (patients and providers) input into the design and development process. This helped us understand the needs and expectations of patients living with OA symptoms from a mobile app that could help them manage their condition on a daily basis and also help them communicate with their providers better and be more informed during visits.

One of the challenges we faced during this study was recruiting patients with OA into an mHealth study. We were using a single mobile phone platform (Android) for our development and this resulted in excluding patients with iOS devices from participating in our usability and feasibility tests. To help with recruitment, it was important to identify potential Android users ahead of time in the clinic. Once we had a pool of Android users who are visiting the clinic, it

was easier to achieve recruitment targets. For a larger study, it is critical to have the app working on both platforms to increase the pool of eligible participants.

## **Conclusions**

TJR App has the potential to be utilized in clinical settings at various stages of OA. For mild to moderate OA patients, TJR App could help track symptoms and understand more about their condition. For moderate to severe OA patients, TJR App can help provide tools to facilitate shared decision making about treatment options and keep track of symptoms as treatments change, allowing to create a track of evidence that is collected directly by the patient. In this exploratory study, we identified the potential of OA-specific mobile app from the perspective of patients. Further studies are needed to understand if the perceived benefits are actualized when the app is in use.

## **LIST OF PUBLICATIONS AND PRODUCTS**

### **Publications**

1. Zheng H, Tulu B, Choi W, et al. Using mHealth App to Support Treatment Decision-Making for Knee Arthritis: Patient Perspective. eGEMs (Generating Evidence & Methods to improve patient outcomes). 2017;5(2):7.
2. Choi W, Zheng H, Franklin P, et al. mHealth technologies for osteoarthritis self-management and treatment: a systematic review. Health informatics journal. 2017:1460458217735676.
3. Choi W, Tulu B, Zheng H, et al., editors. Developing an mHealth Application for Osteoarthritis Patients. Americas Conference on Information Systems (AMCIS); 2016; San Diego, CA.

### **Products**

1. TJR project website (<http://tjrapp.wpi.edu/>): We have set up this website to introduce our project to communities of interest and to the public, providing information about the significance and purpose of the project, an overview of the app's main functionalities, tutorials, publications, and the research team.
2. We developed TJR App including all major functionalities we proposed in the proposal—including pain and activity management (entering data, viewing progress graphs, receiving feedback), custom reminders, and PRO assessments. We also included features such as frequently asked questions and custom feedback based on progress. The final version of TJR App is available at Google Play, the major online app store for Android-based mobile devices, as an open beta product. Anyone who wants to use the app can download it from <https://play.google.com/apps/testing/edu.wpi.tjrapp>. Interested users can use the following username and password combination to test the app (Username: 123, Password: 123).

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